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THE COMBINED EFFECTS OF IONIZING RADIATION AND WEIGHTLESSNESS
ON CALCIUM AND PHOSPHORUS CONTENT IN THE MINERAL FRACTION
OF THE CALCIFIED TISSUES IN THE RAT SKELETON

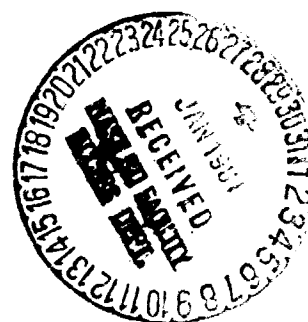
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16. Abstract Phosphorus and calcium content in the ash from skeletal bones (ribs, scapula, vertebra, and crus) of 30 rats exposed to ionizing radiation (800 rads) on the flight of the "Kosmos-690" biosatellite was studied. A 10 percent decrease in ash content coefficient and 29% decrease in phosphorus content was found immediately after the flight, and a 9 percent decrease in phosphorus content persisted after 26 days of readaptation to terrestrial conditions.			
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THE COMBINED EFFECTS OF IONIZING RADIATION AND WEIGHTLESSNESS
ON CALCIUM AND PHOSPHORUS CONTENT IN THE MINERAL FRACTION
OF THE CALCIFIED TISSUES IN THE RAT SKELETON

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It has been previously established that alterations in calcium metabolism occur in the calcified tissues of the skeleton under the influence of certain factors of space flight (acceleration, hypokinesia, weightlessness, etc.) [1, 2]. In experiments on the "Kosmos-605" and "Kosmos-782" biosatellites, according to ^{45}Ca uptake indices in the mineral fraction of calcified tissues, a reduction in stable calcium content and decrease in the specific calcium metabolism activity was found to have occurred. Phosphorus metabolism in the bones of the subject animals did not significantly differ from that in the control group. Based upon these experiments, it was proposed that alterations in calcium metabolism occur primarily as a result of one factor in space flight -- weightlessness [1, 2].

One of the most important factors of space flight is the effect of ionizing radiation, the sources of which are the Earth's radiation belt, cosmic rays, etc. Massive streams of ionizing radiation born of the periodic flares (prominences) on the surface of the Sun are of particular interest when space craft, satellites, and space stations might be affected by massive doses of ionizing radiation [3, 4]. The effects of ionizing radiation on experimental animals (rats) in a satellite were simulated in an experiment aboard the "Kosmos-690" biosatellite. On the 10-day flight the animals were irradiated for 24 hours with an 800 rad dose of ionizing radiation using a source located on the satellite. In this work we studied calcium and phosphorus content in the mineral fraction of the skeletal calcified tissues in the rats.

Material and Methods

30 rats were used in the experiments: 1 -- flight group; 2 -- synchronous experiment group, in the animals of which space flight factors (except weightlessness), including the effect of ionizing radiation in a dose identical to that of the flight group (800 rads), were simulated under terrestrial conditions; 3 -- vivarium ("pure") controls; 4 -- flight group 26 days after landing; 5 -- experiment synchronous with group 4; 6 -- vivarium ("pure") control for group 4. In addition, data obtained in an experiment on rats which had completed a flight on the "Kosmos-605", in which the animals were divided into the same types of groups as those in the "Kosmos-690" biosatellite experiment (without irradiation), were used as an additional comparative control.

The experimental animals were sacrificed after 2 and 26 days following landing. The following bones of the skeleton were studied: vertebral, costal, and scapular bones and crus. Ash content (in percent of dry weight) and calcium and phosphorus content (in percent of ash) were studied using the previously described methodology [1]; the obtained numerical data were statistically treated using Student's method.

Results and Discussion

Ash content in all the skeletal bones under study decreased 3-10%, compared to the vivarium controls, following space flight. As compared to data from [1], this index was 1-12% lower than the control group, i.e., the combined effects of weightlessness and ionizing radiation approximately doubled the reduction in the ash content coefficient. After 26 days of readaptation to terrestrial gravitation, this index increased 2-8% in the flight group, but remained 2-12% lower than that in the identical "Kosmos-605" biosatellite group. In the synchronous experiment for the "Kosmos-690" biosatellite flight group, the ash content coefficient was 2-7% higher than in the flight group, and did not differ in fact from the vivarium control, except in the vertebrae, where it was 2% lower relative to the flight group and 10% lower relative

to the vivarium controls; after 26 days of readaptation it finally normalized and did not differ from that in the vivarium controls. No significant alterations were found in the remaining tissues under study.

Stable calcium content in the ash of the rat calcified tissues from the "Kosmos-690" biosatellite flight group was 3-12% higher than in the identical group from the "Kosmos-605" biosatellite, both immediately after flight and 26 days following landing. Calcium content in the "Kosmos-690" biosatellite flight group was 1-3% higher than in the synchronous experiment and vivarium controls, in which this index was, in fact, identical. After 26 days of readaptation, this index did not differ from that in the flight group, except in the scapula and crus, where it was reduced 4%. An identical picture was found in a comparison with the synchronous experiment and vivarium control. Phosphorus content in the ash of the calcified tissues was characterized by a sharp 22-29% drop relative to the vivarium controls and a 14-21% drop relative to the same index in data from the "Kosmos-605" biosatellite. In the synchronous experiment, phosphorus content in the ash was 15-27% higher than in the flight group, but 4-11% lower than the vivarium controls', except in the crus, where it was identical in both control groups.

In the period of readaptation to terrestrial conditions, phosphorus content in the ash of the calcified tissues increased 2-11% in the flight group, but remained 4-26% lower than in the identical group from the "Kosmos-605" biosatellite, except in the vertebrae and crus, where phosphorus content remained at the same level as it was 2 days after the completion of the flight. A reduction of phosphorus content in the costals, scapulae, and crura was noted in the synchronous experiment and the vivarium control following 26 days of readaptation. Data from the "Kosmos-605" biosatellite showed that calcium content in all the tissues under study became virtually identical in the flight and control groups after the 26-day readaptation period.

Calcium content in the ash of the calcified tissues for the combined effects of ionizing radiation and weightlessness virtually did not differ from that in the synchronous experiment and in the vivarium controls, but was 5-8% higher than with weightlessness alone, which decreased this index 3-6% relative to the respective controls. This index did not change even after 26 days of readaptation in the combined experiment, but remained 3-12% higher than in the experiment with weightlessness.

The combined influence of irradiation and weightlessness leads to a sharp reduction (22-29%) of phosphorus content in the ash from the calcified tissues, compared to the vivarium controls, and 14-21% compared to the influence of weightlessness alone. The effects of weightlessness caused this index to be 4-13% higher than the controls. In the postflight period, phosphorus content increased 2-11% in the combined experiment, but remained reduced in comparison to the control groups and to the experiment in which weightlessness was the only determining factor, and where this index was identical to those in the control groups. The combined effects of ionizing radiation and weightlessness approximately doubled the reduction in the ash content coefficient in comparison with the effect of weightlessness alone. During the postflight period, this index approached that in the synchronous experiment and in the vivarium control.

The data obtained agree with the results of the influence of ionizing radiation on osseous tissue: during identical periods, more pronounced alterations occur in phosphorus metabolism than in calcium metabolism, which reacts to ionizing radiation to a lesser degree [5-7]. It is difficult to draw a definite conclusion based on these experiments; we can only propose that irradiation causes a pronounced alteration in phosphorus content, while weightlessness does not cause marked changes in phosphorus and calcium content in calcified tissues, but only evokes a redistribution of these elements within a bone (epiphysis-diaphysis), which was confirmed in experiments on the "Kosmos-782" biosatellite [2].

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